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IS 11852-9 (2003): Automotive Vehicles - Brakes and Braking Systems, Part 9: Requirements for Vehicles Equipped with Anti-Lock Braking Systems [TED 4: Automotive Braking Systems]

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भाग 9 रोधी-लॉक युक्तियों वाले वाहनों के लिए अपेक्षाएँ

Indian Standard

AUTOMOTIVE VEHICLES — BRAKES AND BRAKING SYSTEMS

PART 9 REQUIREMENTS FOR VEHICLES EQUIPPED WITH ANTI-LOCK BRAKING SYSTEMS

ICS 43.040.40

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

September 2003 Price Group 9

Automotive Braking Systems, Vehicle Testing and Performance Evaluation Sectional Committee, TED 4

FOREWORD

This Indian Standard (Part 9) was adopted by the Bureau of Indian Standards, after the draft finalized by the Automotive Braking Systems, Vehicle Testing and Performance Evaluation Sectional Committee had been approved by the Transport Engineering Division Council.

This standard on brakes and braking systems which was earlier issued in eight parts, has now been revised and issued in nine parts. The other parts are:

(Part 1) : 2001	Terminology
(Part 2) : 2001	General functions and features
(Part 3) : 2001	Performance requirements and evaluation
(Part 4) : 2001	Compressed air and air assisted brakes — Special requirements
(Part 5) : 2001	Compressed air and air assisted brakes — Pressure test connections
(Part 6) : 2001	Vacuum braking systems — Special requirements
(Part 7) : 2001	Inertia dynamometer test method for brake linings
(Part 8) : 2001	Test procedures

IS 11852 (Part 7) : 1995 'Automotive vehicles — Recommendations for brakes and braking systems: Part 7 Model test report' has been withdrawn in this revision and has been replaced with a part covering, 'Inertia dynamometer test methods for brake linings'. In this standard the requirements for vehicles equipped with anti-lock braking devices has been added.

During braking of automotive vehicles, wheels lock if the brake force applied is more than the friction between the road and tyre. This often happens in a panic braking situation, especially on a slippery road. When the front wheels lock, the vehicle slides in the direction of motion and when the rear wheels lock, the vehicle swings around. It is impossible to steer around an obstacle with wheels locked that can result in accidents. Skidding also reduces tyre life. Anti-lock braking system (ABS) prevents wheel lock during panic braking. ABS maintains vehicle stability and ensures steerability during braking, thus avoiding accidents. This part of the standard specifies the requirements for vehicles equipped with the ABS.

In this standard, the following International Standards have been referred for which at present there are no equivalent Indian Standards:

ISO 7638	Road vehicles — Electrical connectors for braking systems
(Part 1) : 1997	Connectors for 24 V nominal supply voltage
(Part 2) : 1997	Connectors for 12 V nominal supply voltage

The composition of the Committee responsible for the formulation of this standard is given at Annex F.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

AMENDMENT NO. 1 MAY 2004
TO
IS 11852 (PART 9) : 2003 AUTOMOTIVE VEHICLES —BRAKES AND BRAKING SYSTEMS

PART 9 REQUIREMENTS FOR VEHICLES EQUIPPED WITH ANTI-LOCK BRAKING SYSTEMS

(*Page* 4, *clause* **6.3.1**) — Substitute the following for the existing:

'**6.3.1** The wheels directly controlled by an anti-lock system shall not lock when the full force is suddenly applied on the control device, on the road surfaces specified in **6.2.2**, at an initial speed of 40 km/h and at a high initial speed as indicated in the table below:

Type of Road Surface (1)	*Vehicle Category* (2)	*Maximum Test Speed* (3)
High-adhesion surface	All categories except N2, N3 laden	0.8 *V*max ≤ 120 km/h
	N2, N3 laden	0.8 *V*max ≤ 80 km/h
Low-adhesion surface	M1, N1	0.8 *V*max ≤ 120 km/h
	M2, M3, N2 except tractors for semi-trailer	0.8 *V*max ≤ 80 km/h
	N2 tractors for semi-trailer, N3	0.8 *V*max ≤ 70 km/h

(TED 4)

Reprography Unit, BIS, New Delhi, India

Indian Standard

AUTOMOTIVE VEHICLES — BRAKES AND BRAKING SYSTEMS

PART 9 REQUIREMENTS FOR VEHICLES EQUIPPED WITH ANTI-LOCK BRAKING SYSTEMS

1 SCOPE

1.1 This standard (Part 9) covers the requirements for braking performance for road vehicles fitted with anti-lock systems.

In addition, motor vehicles which are authorized to draw a trailer of categories T3 and T4, and trailers of categories T3 and T4 equipped with compressed-air braking systems shall, when the vehicles are laden, meet the requirements for compatibility set out in Annex A.

1.2 The anti-lock systems known at present comprise a sensor or sensors, a controller or controllers and a modulator or modulators. Any device of a different design, which may be introduced in the future, will be deemed to be an anti-lock braking system within the meaning of this standard, if it provides performance equal to that prescribed in this standard.

2 REFERENCES

The following standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

IS No.	*Title*
9211 : 1979	Denominations and definitions of weights of road vehicles (*first revision*)
11852	Automotive vehicles — Brakes and braking systems:
(Part 2) : 2001	General functions and features (*first revision*)
(Part 3) : 2001	Performance requirements and evaluation (*first revision*)
(Part 4) : 2001	Compressed air and air assisted brakes — Special requirements (*first revision*)
(Part 5) : 2001	Compressed air and air assisted brakes — Pressure test connections
13461 : 1992	Automotive vehicles — Electrical connections between towing vehicles and towed vehicles with 6 or 12 V electrical equipment — Type 12 N (Normal)
13491 : 1992	Automotive vehicles — Electrical connections between towing vehicles and towed vehicles with 24 V electrical equipment — Type 24 N (Normal)

3 DEFINITIONS

In addition to the definitions given hereunder, the symbols and definitions as given in Annex B may also be referred.

3.1 Anti-lock Device/System, means device which automatically controls the level of slip, in the direction of rotation of the wheel(s), on one or more wheels of a vehicle during braking.

3.2 Sensor, means the component responsible for sensing the conditions of rotation of the wheel (s) or the dynamic condition of the vehicle and for transmitting this information to the controller.

3.3 Controller, means the component responsible for evaluating the information supplied by the sensor and for transmitting an order to the modulator.

3.4 Modulator, means the component responsible for modulating the force developed by the brake actuators as a function of the order received from the controller.

3.5 Directly Controlled Wheel, means a wheel whose braking force is modulated according to data provided at least by its own sensor.

3.6 Indirectly Controlled Wheel, means a wheel whose braking force is modulated according to data provided by the sensor(s) of other wheel(s).

NOTE — Anti-lock systems with select-high control are deemed to include both directly and indirectly controlled wheels; in systems with select-low control, all sensed wheels are deemed to be directly controlled wheels.

3.7 Full Cycling, means that the anti-lock system is repeatedly modulating the brake force to prevent the directly controlled wheels from locking. Brake applications where modulation only occurs once during the stop shall not be considered to meet this definition. In the case of trailers with pneumatic braking systems, full cycling of the anti-lock braking system is only assured when the pressure available at any brake actuator of a directly controlled wheel is more than 1 bar above the maximum cycling pressure throughout a given test. The supply pressure available may not be increased above 8 bar.

4 TYPES OF ANTI-LOCK SYSTEMS

4.1 A motor vehicle is deemed to be equipped with an anti-lock system within the meaning of **A-1**, if one of the following systems is fitted.

4.1.1 *Category 1 Anti-lock System*

A vehicle equipped with a Category 1 anti-lock system shall meet all the relevant requirements of this standard.

4.1.2 *Category 2 Anti-lock System*

A vehicle equipped with a Category 2 anti-lock system shall meet all the relevant requirements of this standard, except those of **6.3.5**.

4.1.3 *Category 3 Anti-lock System*

A vehicle equipped with a Category 3 anti-lock system shall meet all the relevant requirements of this standard, except those of **6.3.4** and **6.3.5**. On such vehicles, any individual axle (or bogie) which does not include at least one directly controlled wheel shall fulfil the conditions of adhesion utilization and the wheel-locking sequence of Annex A instead of adhesion utilization requirements of **6.2** with regard to the braking rate and the load respectively. However, if the relative positions of adhesion utilization curves do not meet requirements of **A-3.1.1**, a check shall be made to ensure that the wheels on at least one rear axle do not lock before those on front axles or axles under the conditions prescribed in **A-3.1.1** and **A-3.1.4**. These requirements may be checked on high and low adhesion road surfaces (about 0.8 and 0.3 maximum) by modulating the service braking control force.

NOTE — It is recommended that anti-lock braking devices fitted on N3 vehicles authorized to draw category T4 trailers and M3 vehicles shall be of category 1.

4.2 A trailer is deemed to be equipped with an anti-lock system within the meaning of **A-1** when at least two wheels on opposite sides of the vehicle are directly controlled and all remaining wheels are either directly or indirectly controlled by the anti-lock system. In the case of full trailers, at least two wheels on one front axle and two wheels on one rear axle are directly controlled with each of these axles having at least one independent modulator and all remaining wheels are either directly or indirectly controlled. In addition, the anti-lock equipped trailer shall meet one of the following conditions:

4.2.1 *Category A Anti-lock System for Trailers*

A trailer equipped with a Category A anti-lock system shall meet all the relevant requirements of this standard.

4.2.2 *Category B Anti-lock System for Trailers*

A trailer equipped with a Category B anti-lock system shall meet all the relevant requirements of this standard, except **7.3.2**.

5 GENERAL REQUIREMENTS

5.1 Any electrical failure or sensor anomaly that affects the system with respect to the functional and performance requirements in this standard, including those in the supply of electricity, the external wiring to the controller(s), the controller(s) and the modulator(s) shall be signalled to the driver by a specific optical warning signal. Such signals shall be visible in daylight.

NOTE — Until uniform test procedures have been agreed, the manufacturer shall provide the test agency with an analysis of potential failures within the controller(s) and their effects. This information shall be subject to discussion and agreement between the test agency and the vehicle manufacturer.

5.1.1 The warning signal shall light up when the anti-lock system is energized and with the vehicle stationary and it shall be verified that none of the above-mentioned defects are present before extinguishing the signal.

5.1.2 The static sensor check may verify that a sensor was not functioning the last time that the vehicle was at a speed greater than 10 km/h. Also during this verification phase, the electrically controlled (pneumatic) modulator valve(s) shall cycle at least once.

NOTE — The warning signal may light up again when the vehicle is stationary, provided that it is extinguished before the vehicle speed reaches 10 km/h when no defect is present.

5.2 Motor vehicles equipped with an anti-lock system and authorized to draw a trailer equipped with such a system, with the exception of vehicles of Categories M1 and N1, shall be fitted with a separate optical warning signal for the anti-lock system of the trailer, meeting the requirements of **5.1**.

This warning signal shall not light up when a trailer without an anti-lock braking system is coupled or when no trailer is coupled. This function shall be automatic.

5.3 The electrical connections used for the anti-lock systems of all vehicles including drawing vehicles and trailers shall be effected by special connector conforming to ISO 7638 (Parts 1 and 2).

NOTE — To ensure compatibility of all vehicles until the special ISO connector is in general use, trailers shall also fulfil one of the following two conditions:

a) The trailer anti-lock system shall be capable of operation via the stop lamp circuit [using pin 4 of the ISO 7638 (24N) connector and without exceeding the present limits of the stop lamp circuit] and the trailer shall be equipped with an optical warning signal, within the field of view of the driver's rear-view mirror and visible even in day light, to warn him of any break in the supply of electricity and/or in the wiring external to the controller of the anti-lock system of the trailer; or

b) The trailer braking system shall satisfy the requirements of Annex A.

The wiring specification as per ISO 7638 (Parts 1 and 2) for the trailer may only be reduced if the trailer is installed with its own independent fuse. The rating of the fuse shall be such that the current rating of the conductors is not exceeded. With the exception of vehicles of category N3 and O4 and until a uniform international standard has been agreed, the electrical connection between drawing vehicles and trailers equipped with a 12 V electrical system shall conform with IS 13461.

5.4 In the event of failure in the anti-lock system, the residual braking performance shall be that prescribed for the vehicle in question in the event of failure of part of the transmission of the service braking system [*see* **4.2.1.4** of IS 11852 (Part 2)]. This requirement shall not be construed as a departure from the requirements concerning secondary braking. In the case of trailers the residual braking performance in the event of a defect in the anti-lock system according to **5.1** shall be at least 80 percent of the prescribed laden performance for the service braking system of the relevant trailer.

5.5 The operation of the anti-lock system shall not be adversely affected by magnetic or electrical fields.

NOTE — Until uniform test procedures have been agreed, the manufacturer shall provide the test agency with their test procedures and results.

5.6 A manual device may not be provided to disconnect or change the control mode of the anti-lock system, except on off-road motor vehicles of Categories N2 and N3. Where a device is fitted to N2 or N3 category vehicles, the following conditions shall be met.

NOTE — It is understood that devices changing the control mode of the anti-lock system are not subject to 5.6 if in the changed control mode condition all requirements for the category of anti-lock system, with which the vehicle is equipped, are fulfilled. However in this case 5.6.2, 5.6.3, and 5.6.4 shall be met.

5.6.1 The motor vehicle with the anti-lock system disconnected or the control mode changed by the device referred to in **5.6** shall satisfy all the relevant requirements given in Annex A.

5.6.2 An optical warning signal shall inform the driver that the anti-lock system has been disconnected or the control mode changed; the anti-lock failure warning signal may be used for this purpose.

5.6.3 The anti-lock system shall automatically be reconnected/returned to on-road mode when the ignition (start) device is again set to the 'ON' (run) position.

5.6.4 The vehicle user's handbook provided by the manufacturer should warn the driver of the consequences of manual disconnection or mode change of the anti-lock system.

5.6.5 The device referred to in **5.6** may, in conjunction with the drawing vehicle, disconnect/change the control mode of the anti-lock system of the trailer; a separate device for the trailer alone is not permitted.

6 SPECIAL PROVISIONS CONCERNING MOTOR VEHICLES

6.1 Energy Consumption

Power-driven vehicles equipped with anti-lock systems shall maintain their performance when the service braking control device is fully applied for long periods. Compliance with this requirement shall be verified by means of the following tests.

6.1.1 *Test Procedure*

6.1.1.1 The initial-energy level in the energy storage device(s) shall be that specified by the manufacturer. This level shall be at least such as to ensure the efficiency prescribed for service braking when the vehicle is laden. The energy storage device(s) for pneumatic auxiliary equipment shall be isolated.

6.1.1.2 From an initial speed of not less than 50 km/h or 80 percent of the maximum design speed of the vehicle whichever is lower, on a surface with a coefficient of adhesion of 0.3 or less (*see* Annex E), the brakes of the laden vehicle shall be fully applied for a time t, during which time the energy consumed by the indirectly controlled wheels shall be taken into consideration and all directly controlled wheels shall remain under control of the anti-lock system throughout that time.

NOTE — Until such test surfaces become generally available, tyres at the limit of wear, and higher values up to 0.4 may be used at the discretion of the test agency. The actual value obtained and the type of tyres and surface shall be recorded.

6.1.1.3 The vehicle's engine shall then be stopped or the supply to the energy transmission storage device(s) cut off.

6.1.1.4 The service braking control device shall then be fully actuated four times in succession with the vehicle stationary.

6.1.1.5 When the control device is applied for the fifth time, it shall be possible to brake the vehicle with at least the performance prescribed for secondary braking of the laden vehicle.

6.1.1.6 During the tests, in the case of a power-driven vehicle authorized to draw a trailer equipped with a compressed-air braking system, the supply line shall be stopped and an energy storage device of 0.5 litre capacity shall be connected to the pneumatic control line in accordance with **3.2.2.3** of IS 11852 (Part 4). When the brakes are applied for the fifth time, as provided in **6.1.1.5**, the energy level supplied to the control line shall not be below half the level obtained at a full application starting with the initial energy level.

6.1.2 Additional Requirements

6.1.2.1 The coefficient of adhesion of the road surface shall be measured with the vehicle under test, by the method described in **C-1.1**.

6.1.2.2 The braking test shall be conducted with the engine disconnected and idling and with the vehicle laden.

6.1.2.3. The braking time t shall be determined by the formula: $t = V_{max} /7$ (but not less than 15 s) where t is expressed in seconds and V_{max} represents the maximum design speed of the vehicle expressed in km/h, with an upper limit of 160 km/h.

6.1.2.4 If the time t cannot be completed in a single braking phase, further phases may be used, up to a maximum of four in all.

6.1.2.5 If the test is conducted in several phases, no fresh energy shall be supplied between the phases of the test.

From the second phase, the energy consumption corresponding to the initial brake application may be taken into account, by subtracting one full brake application from the four full applications prescribed in **6.1.1.4**, **6.1.1.5** and **6.1.2.6** for each of the second, third and fourth phases used in the test prescribed in **6.1.1**, as applicable.

6.1.2.6 The performance prescribed in **6.1.1.5** shall be deemed to be satisfied if, at the end of the fourth application, with the vehicle stationary, the energy level in the storage device(s) is at or above that required for secondary braking with the laden vehicle.

6.2 Utilization of Adhesion

6.2.1 The utilization of adhesion by the anti-lock system takes into account the actual increase in braking distance beyond the theoretical minimum. The anti-lock system shall be deemed to be satisfactory when the condition $\epsilon \geq 0.75$ is satisfied, where ϵ represents the adhesion utilized, as defined in **C-1.2**.

6.2.2 The adhesion utilization ϵ shall be measured on road surfaces with a coefficient of adhesion of 0.3 or less, and of about 0.8 (dry road), with an initial speed of 50 km/h or 80 percent of the maximum design speed whichever is lower. To eliminate the effects of differential brake temperatures it is recommended that z_{AL} be determined prior to the determination of k.

NOTE — Until such test surfaces become generally available, tyres at the limit of wear, and higher values up to 0.4 may be used at the discretion of the test agency. The actual value obtained and the type of tyres and surface shall be recorded.

6.2.3 The test procedure to determine the coefficient of adhesion (k) and the formulae for calculation of the adhesion utilization ϵ shall be those laid down in Annex C.

6.2.4 The utilization of adhesion by the anti-lock system shall be checked on complete vehicles equipped with anti-lock systems of Categories 1 or 2. In the case of vehicles equipped with Category 3 anti-lock systems, only the axle(s) with at least one directly controlled wheel shall satisfy this requirement.

6.2.5 The condition $\epsilon \geq 0.75$ shall be checked with the vehicle laden and unladen. The laden test on the high adhesion surface may be omitted if the prescribed force on the control device does not achieve full cycling of the anti-lock system. For the unladen test, the control force may be increased up to 100 daN if no cycling is achieved with its full force value. If 100 daN is insufficient to make the system cycle, then this test may be omitted. For air braking systems the air pressure may not be increased above the cut-out pressure for the purpose of this test.

NOTE — 'Full force' means the maximum force laid down in IS 11852 (Part 3) for the category of vehicles; a higher force may be used if required to activate the anti-lock system.

6.3 Additional Checks

The following additional checks shall be carried out, engine disconnected, with the vehicle laden and unladen.

6.3.1 The wheels directly controlled by an anti-lock system shall not lock when the full force is suddenly applied on the control device, on the road surfaces specified in **6.2.2**, at an initial speed of 40 km/h and at a high initial speed as indicated below:

Type of Road Surface	*Vehicle Category*	*Maximum Test Speed*
High-adhesion surface	All categories except N2, N3 laden	$0.8\ V_{max} \leq 120$ km/h
	N2, N3 laden	$0.8\ V_{max} \leq 80$ km/h
	M1, N1	$0.8\ V_{max} \leq 120$ km/h
Low-adhesion surface	M2, M3, N2 except tractors for semi-trailer	$0.8\ V_{max} \leq 80$ km/h
	N2 tractors for semi-trailer, N3	$0.8\ V_{max} \leq 70$ km/h

6.3.2 When an axle passes from a high-adhesion surface (k_H) to a low-adhesion surface (k_L) where $k_H \geq 0.5$ and $k_H/k_L \geq 2$ with the full force applied on the control device, the directly controlled wheels shall not lock. The running speed and the instant of applying the brakes shall be so calculated that, with the anti-lock system fully cycling on the high-adhesion surface, the passage from one surface to the other is made at high and at low speed, under the conditions laid down in **6.3.1**.

6.3.3 When a vehicle passes from a low-adhesion surface (k_L) to a high-adhesion surface (k_H) where $k_H \geq 0.5$ and $k_H/k_L \geq 2$, with the full force applied on the control device, the deceleration of the vehicle shall rise to the appropriate high value within a reasonable time and the vehicle shall not deviate from its initial course. The running speed and the instant of applying the brakes shall be so calculated that, with the anti-lock system fully cycling on the low-adhesion surface, the passage from one surface to the other occurs at approximately 50 km/h or 80 percent of the design speed of the vehicle whichever is lower.

6.3.4 In the case of vehicles equipped with anti-lock systems of Categories 1 or 2, when the right and left wheels of the vehicle are situated on surfaces with differing coefficients of adhesion (k_H and k_L), where $k_H \geq 0.5$ and $k_H/k_L \geq 2$, the directly controlled wheels shall not lock when the full force is suddenly applied on the control device at a speed of 50 km/h or 80 percent of the design speed whichever is lower.

6.3.5 Furthermore, laden vehicles equipped with anti-lock systems of Category 1 shall, under the conditions of **6.3.4** satisfy the prescribed braking rate as in Annex D.

6.3.6 However, in the tests provided in **6.3.1** to **6.3.5**, brief periods of wheel-locking shall be allowed. Furthermore, wheel-locking is permitted when the vehicle speed is less than 15 km/h; likewise, locking of indirectly controlled wheels is permitted at any speed, but stability and steerability shall not be affected.

6.3.7 During the tests provided in **6.3.4** and **6.3.5**, steering correction is permitted if the angular rotation of the steering control is within 120° during the initial 2s, and not more than 240° in all. Furthermore, at the beginning of these tests the longitudinal median plane of the vehicle shall pass over the boundary between the high-and low-adhesion surfaces and during these tests no part of the (outer) tyres shall cross this boundary.

NOTES

1 'Full force' means the maximum force laid down in IS 11852 (Part 3) for the category of vehicles; a higher force may be used if required to activate the anti-lock system.

2 The purpose of this test is to check that the wheels do not lock and that the vehicle remains stable; it is not necessary, therefore, to make complete stops and bring the vehicle to a halt on the low-adhesion surface.

3 k_H is the high-adhesion surface coefficient k_L is the low-adhesion surface coefficient k_H and k_L are measured as laid down in Annex C.

4 To ensure compatibility of all vehicles until the special ISO connector is in general use, trailers shall also fulfil one of the following two conditions:

a) the trailer anti-lock system shall be capable of operation via the stop lamp circuit [using pin 4 of the IS 7638 (Part 1)] connector and without exceeding the present limits of the stop lamp circuit, and the trailer shall be equipped with an optical warning signal, within the field of view of the driver's rear-view mirror and visible even in day light, to warn him of any break in the supply of electricity and/or in the wiring external to the controller of the anti-lock system of the trailer; or

b) the trailer braking system shall satisfy the requirements of Annex A.

The wiring specification as per ISO 7638 (Parts 1 and 2) for the trailer may only be reduced if the trailer is installed with its own independent fuse. The rating of the fuse shall be such that the current rating of the conductors is not exceeded. With the exception of vehicles of category N3 and O4 and until a uniform international standard has been agreed, the electrical connection between drawing vehicles and trailers equipped with a 12 V electrical system shall conform with IS 13461.

7 SPECIAL PROVISIONS CONCERNING TRAILERS

7.1 Energy Consumption

Trailers equipped with anti-lock systems shall be so designed that, even after the service braking control device has been fully applied for some time, the vehicle retains sufficient energy to bring it to a halt within a reasonable distance.

7.1.1 Compliance with the above requirement shall be checked by the procedure specified below, with the vehicle unladen, on a straight and level road with a surface having a good coefficient of adhesion and with the brakes adjusted as closely as possible and with the proportioning/load-sensing valve (if fitted) held in the 'laden' position throughout the test.

NOTE — If the coefficient of adhesion of the track is too high, preventing the anti-lock system from cycling then the test may be carried out on a surface with a lower coefficient of adhesion.

7.1.2 In the case of compressed-air braking systems, the initial energy level in the energy transmission storage device(s) shall be equivalent to a pressure of 8.0 bar at the coupling head of the trailer's supply line.

7.1.3 With an initial vehicle speed of at least 30 km/h the brakes shall be fully applied for a time, t = 15 s, during which all wheels shall remain under control of the anti-lock system. During this test, the supply to the energy transmission storage device(s) shall be cut off. If the time t = 15 s cannot be completed in a single braking phase, further phases may be used. During these phases no fresh energy shall be supplied to the energy transmission storage device(s) and, as from the second phase, the additional energy consumption for filling the actuators is to be taken into account, for example, by the following test procedure:

The pressure in the reservoir(s) when starting the first phase is to be that stated in **7.1.2**. At the beginning of the following phase(s) the pressure in the reservoir(s) after application of the brakes shall be not less than the pressure in the reservoir(s) at the end of the preceding phase.

At the subsequent phase(s), the only time to be taken into account is from the point at which the pressure in the reservoir(s) is equal to that at the end of the preceding phase.

7.1.4 At the end of the braking, with the vehicle stationary, the service braking control device shall be fully actuated four times. During the fifth application, the pressure in the operating circuit shall be sufficient to provide a total braking force at the periphery of the wheels equal to not less than 22.5 percent of the maximum stationary wheel load and without causing an automatic application of any braking system not being under the control of the anti-lock system.

7.2 Utilization of Adhesion

7.2.1 Braking systems equipped with an anti-lock system shall be deemed acceptable when the condition $\epsilon \geq 0.75$ is satisfied, where ϵ represents the adhesion utilized, as defined in **C-2**. This condition shall be verified with the vehicle unladen, on a straight and level road with a surface having a good coefficient of adhesion.

NOTES

1 If the coefficient of adhesion of the track is too high, preventing the anti-lock system from cycling then the test may be carried out on a surface with a lower coefficient of adhesion.

2 In case of trailers fitted with load sensing device the pressure setting may be increased to ensure full cycling.

7.2.2 To eliminate the effects of differential brake temperatures, it is recommended to determine z_{RAL} prior to the determination of k_R.

7.3 Additional Checks

7.3.1 At speeds exceeding 15 km/h, the wheels directly controlled by an anti-lock system shall not lock when the full force is suddenly applied on the control device of the drawing vehicle. This shall be checked, under the conditions prescribed in **7.2**, at initial speeds of 40 km/h and 80 km/h or 80 percent of the maximum speed of the vehicle, whichever is lower.

NOTE — 'Full force' means the maximum force laid down in IS 11852 (Part 3) for the category of vehicles; a higher force may be used if required to activate the anti-lock system.

7.3.2 The provisions of this para shall only apply to trailers equipped with an anti-lock system of Category A. When the right and left wheels are situated on surfaces which produce differing maximum braking rates (z_{RALH} and z_{RALL}),

where

$$z_{RALH} / \epsilon_H \geq 0.5 \quad \text{and} \quad z_{RALH} / z_{RALL} \geq 2$$

the directly controlled wheels shall not lock when the full force is suddenly applied on the control device of the drawing vehicle at a speed of 50 km/h or 0.8 times the maximum speed of the coupled motor vehicle whichever is lower. The ratio z_{RALH} / z_{RALL} may be ascertained by the procedure in **C-2** or by calculating the ratio z_{RALH} / z_{RALL}. Under this condition the unladen vehicle shall satisfy the prescribed braking rate in Annex D.

NOTE — In case of trailers fitted with load sensing device the pressure setting may be increased to ensure full cycling.

7.3.3 At vehicle speeds ≥ 15 km/h the directly controlled wheels are permitted to lock for brief periods, but at speeds < 15 km/h any locking is permissible. Indirectly controlled wheels are permitted to lock at any speed but in all cases stability shall not be affected.

ANNEX A

(*Clauses* 1.1, 4.1.3, 5.3, 5.6.1 *and* 6.3.7)

DISTRIBUTION OF BRAKING EFFORT AMONG VEHICLE AXLES

A-1 GENERAL REQUIREMENTS

This Annex is applicable to motor vehicles equipped with ABS and authorized to draw trailers of Category T3 and T4 and trailers of Category T3 and T4 equipped with compressed air braking system in laden condition. However, vehicles — other than those of Category M1 — which are equipped with an anti-lock system as defined in this standard, shall also meet the requirements of **A-7** and **A-8** if they are in addition fitted with a special automatic device which controls the distribution of braking among the axles. In the event of failure of its control, it shall be possible to stop the vehicle as stipulated under **A-6**.

A-2 SYMBOLS

i = axle index (i = 1, front axle; i = 2, second axle; etc)

P_i = normal reaction of road surface on axle i under static conditions

N_i = normal reaction of road surface on axle i under braking

T_i = force exerted by the brakes on axle i under normal braking conditions on the road

f_i = T_i/N_i adhesion used by axle i

NOTE — Adhesion curves used by each axle means curves showing the adhesion used by axle i plotted against the vehicle braking rate under specified load conditions.

J = deceleration of vehicle

g = acceleration due to gravity $g = 9.81$ m/s²

z = braking rate of vehicle = J/g

NOTE — For semi-trailers, z is the braking force divided by the static mass on the semi-trailer axle(s).

P = mass of vehicle
h = height above ground of centre of gravity specified by the manufacturer and agreed by the test agency conducting the approval test
E = wheelbase
k = theoretical coefficient of adhesion between tyre and road
k_c = correction factor — semi-trailer laden
k_v = correction factor — semi-trailer unladen
T_M = sum of braking forces at the periphery of wheels of drawing vehicles for trailers or semi-trailers
P_M = total normal static reaction between road surface and wheels of drawing vehicles for trailers or semi-trailers as referred to in A-3.1.4 and A-3.1.5 respectively
P_m = pressure at coupling head of control line
T_R = sum of braking forces at periphery of all wheels of trailer or semi-trailer
P_R = total normal static reaction of road surface on wheels of trailer or semi-trailer
$P_{R\,max}$ = value of P_R at maximum mass of semi-trailer
E_R = distance between king-pin and centre of axle or axles of semi-trailer
h_R = height above ground of centre of gravity of semi-trailer specified by the manufacturer and agreed by the test agency conducting the approval test.

A-3 REQUIREMENTS FOR MOTOR VEHICLES

A-3.1 Two-Axle Vehicles

A-3.1.1 *For All Categories of Vehicles for k Values Between 0.2 and 0.8*

$$z \geq 0.1 + 0.85\,(k - 0.2)$$

For all states of load of the vehicle, the adhesion curve of the front axle shall be situated above that of the rear axle:

For all braking rates of between 0.15 and 0.30 in the case of all categories other than M1 and N1.

NOTE — The provisions of A-3.1.1 do not affect the requirements of IS 11852 (Part 3) relating to the braking efficiency. However, if, when verifying the provisions of A-3.1.1 braking efficiencies are obtained which are higher than those prescribed in IS 11852 (Part 3), the provisions relating to the adhesion utilization curve shall be applied within the area of Fig. 1 defined by the straight lines $k = 0.8$ and $z = 0.8$.

This condition is also considered satisfied if, for braking rates between 0.15 and 0.30 the adhesion utilization curves for each axle are situated between two parallels to the line of ideal adhesion utilization given by the equations $k = z + 0.08$ and $k = z - 0.08$ as shown in Fig. 1, and the adhesion utilization curve for the rear axle, for braking rates $z \geq 0.3$ complies with the relation:

$$z \geq 0.3 + 0.74\,(k - 0.38).$$

A-3.1.2 *In the Case of a Motor Vehicle Authorized to Draw Trailers of Category T3 or T4 Fitted with Compressed-Air Braking Systems*

A-3.1.2.1 When tested with the energy source stopped, the supply line blocked off and a reservoir of 0.5 litre capacity connected to the control line, and the system at cut-in and cut-out pressures, the pressure at full application of the service braking system control shall be between 6.5 and 8.5 bar at the coupling heads of the supply line and the control line, irrespective of the load condition of the vehicle. These pressures shall be demonstrably present in the drawing vehicle when uncoupled from the trailer. The compatibility bands in Fig 2, 3 and 4 shall not be extended beyond 7.5 bar.

A-3.1.2.2 It shall be ensured that at the coupling head of the supply line a pressure of at least 7 bar is available when the system is at cut-in pressure; this pressure shall be demonstrated without applying the service braking system.

A-3.1.3 *Verification of the Requirements of A-3.1.1*

In order to verify the requirements the manufacturer shall provide the adhesion utilization curves for the front and rear axles calculated by the following formulae:

$$f_1 = T_1/N_1 = T_1 / [P_1 + z\,(h/E)\,P\,];$$

$$f_2 = T_2/N_2 = T_2 / [P_2 - z\,(h/E)\,P\,];$$

The graphs shall be plotted in laden condition of the vehicle. Where provision is made for several possibilities of load distribution, the one whereby the front axle is the most heavily laden shall be the one to be taken into consideration.

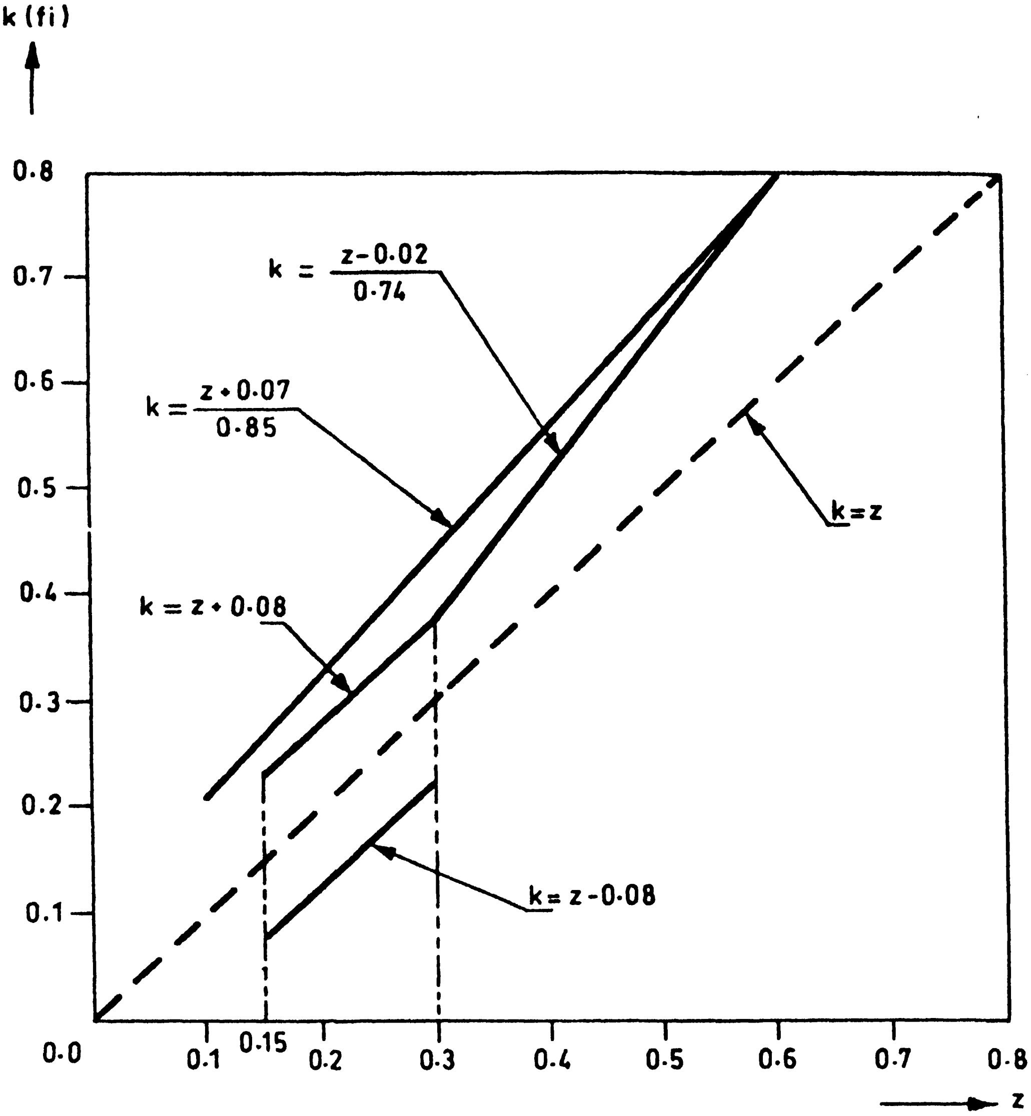
A-3.1.4 *Drawing Vehicles Other Than Tractive Units for Semi-trailers*

A-3.1.4.1 In the case of a motor vehicle authorized to draw trailers of Category T3 or T4 fitted with compressed-air braking systems, the permissible relationship between the braking rate T_M / P_M and the pressure P_m shall be within the areas shown in Fig. 2.

A-3.1.5 *Tractive Units for Semi-trailers*

A-3.1.5.1 *Tractive units with unladen semi-trailer*

An unladen articulated combination is considered to be a tractive unit in running order, with the driver on board, coupled to an unladen semi-trailer. The dynamic load of the semi-trailer on the tractive unit shall be represented by a static mass, mounted at the location of the king pin of the fifth wheel coupling, equal to 15 percent of the maximum mass on the coupling. The braking forces shall continue to be regulated between the state of the tractive unit with semi-trailer (unladen) and that of the tractive unit alone (without semi-trailer); the braking forces relating to the tractive unit alone shall be verified.



NOTE — The lower limit of the corridor is not applicable for the adhesion utilization of the rear axle.

FIG. 1 MOTOR VEHICLES (OTHER THAN THOSE OF CATEGORY M1 AND N AND FULL TRAILERS)

A-3.1.5.2 *Tractive units with laden semi-trailer*

A laden articulated combination shall be considered to be a tractive unit in running order with the driver on board coupled to a laden semi-trailer. The dynamic load of the semi-trailer on the tractive unit shall be represented by a static mass P_s, mounted at the location of the king pin of the fifth wheel coupling, equal to:

$$P_s = P_{s0} (1 + 0.45 z)$$

where P_{s0} represents the difference between the maximum laden mass of the tractive unit and its unladen mass.

For h the following value shall be taken:

$$h = (h_0 P_0 + h_s P_s) / P$$

where

h_0 = height of the centre of gravity of the tractive unit,
h_s = height of the coupling on which the semi-trailer rests,
P_0 = unladen mass of the solo tractive unit.

$$P = P_0 + P_s = P_1 + P_2$$

A-3.1.5.3 In the case of a vehicle fitted with a compressed-air braking system, the permissible relationship between the braking rate T_M / P_M and the pressure P_m shall be within the areas shown in Fig. 3.

A-3.2 Vehicles with More than Two Axles

The requirements of A-3.1 shall apply to vehicles with more than two axles. The requirements of A-3.1.1 with respect to wheel-lock sequence shall be considered to be met, if in the case of braking rates of between 0.15 and 0.30, the adhesion used by at least one of the front axles shall be greater than that used by at least one of the rear axles.

A-4 REQUIREMENTS FOR SEMI-TRAILERS

A-4.1 For Semi-trailers Fitted with Compressed-Air Braking Systems

The permissible relationship between the braking rate T_R / P_R and the pressure P_m shall lie within two areas derived from Figs. 4 and 5 for the laden and unladen states of load. This requirement shall be met for all permissible load conditions of the semi-trailer axles.

A-5 REQUIREMENTS FOR FULL AND CENTRE-AXLE TRAILERS

A-5.1 For Full Trailers Fitted with Compressed-Air Braking Systems

A-5.1.1 The requirements set out in **A-3.1** shall apply to twin axle trailers (except where the axle spread is less than 2 m).

A-5.1.2 Full trailers with more than two axles shall be subject to the requirements contained in **A-3.2**.

A-5.1.3 The permissible relationship between the braking rate T_R / P_R and the pressure P_m, shall lie within the designated areas in Fig. 2 for the laden and unladen states of load.

A-5.2 For Centre-Axle Trailers Fitted with Compressed-Air Braking Systems

A-5.2.1 The permissible relationship between the braking rate T_R / P_R and the pressure P_m shall lie within two areas derived from Fig. 2, by multiplying the vertical scale by 0.95, for the laden and unladen states of load.

A-6 CONDITIONS TO BE FULFILLED IN THE CASE OF FAILURE OF THE BRAKING DISTRIBUTION SYSTEM

When the requirements of this Annex are fulfilled by means of a special device (for example, controlled mechanically by the suspension of the vehicle), it shall be possible, in the event of the failure of this device or its means of control, to stop the vehicle under the conditions specified for secondary braking in the case of motor vehicles; for those vehicles authorized to draw a trailer fitted with air brakes, it shall be possible to achieve a pressure at the coupling head of the control line within the range specified in **A-3.1.2**. In the event of failure of the means of controlling the device in trailers and semi-trailers, a braking rate of at least 30 percent of the service braking system performance prescribed for the vehicle in question shall be attained.

A-7 MARKINGS

A-7.1 Vehicles which meet the requirements of this Annex, by means of a device mechanically controlled by the suspension of the vehicle, shall be marked to show the useful travel of the device between the positions corresponding to vehicle unladen and laden states respectively and any further information to enable the setting of the device to be checked.

A-7.1.1 When a load sensing device is controlled via the suspension of the vehicle by any other means, the vehicle shall be marked with information to enable the setting of the device to be checked.

A-7.2 When the requirements of this Annex are met by means of a device which modulates the air pressure in the brake transmission, the vehicle shall be marked to show the axle loads at the ground, the nominal outlet pressures of the device and an inlet pressure of not less than 80 percent of the maximum design inlet pressure, as declared by the vehicle manufacturer, for the following states of load.

A-7.2.1 Technically permissible maximum axle load for the axle(s) which control(s) the device.

A-7.2.2 Axle load(s) corresponding to the mass of the vehicle in running order as defined in IS 9211.

A-7.2.3 The axle load(s) approximating to the vehicle with proposed bodywork in running order where the axle load(s) mentioned in **A-7.2.2** relate(s) to the vehicle chassis with cab.

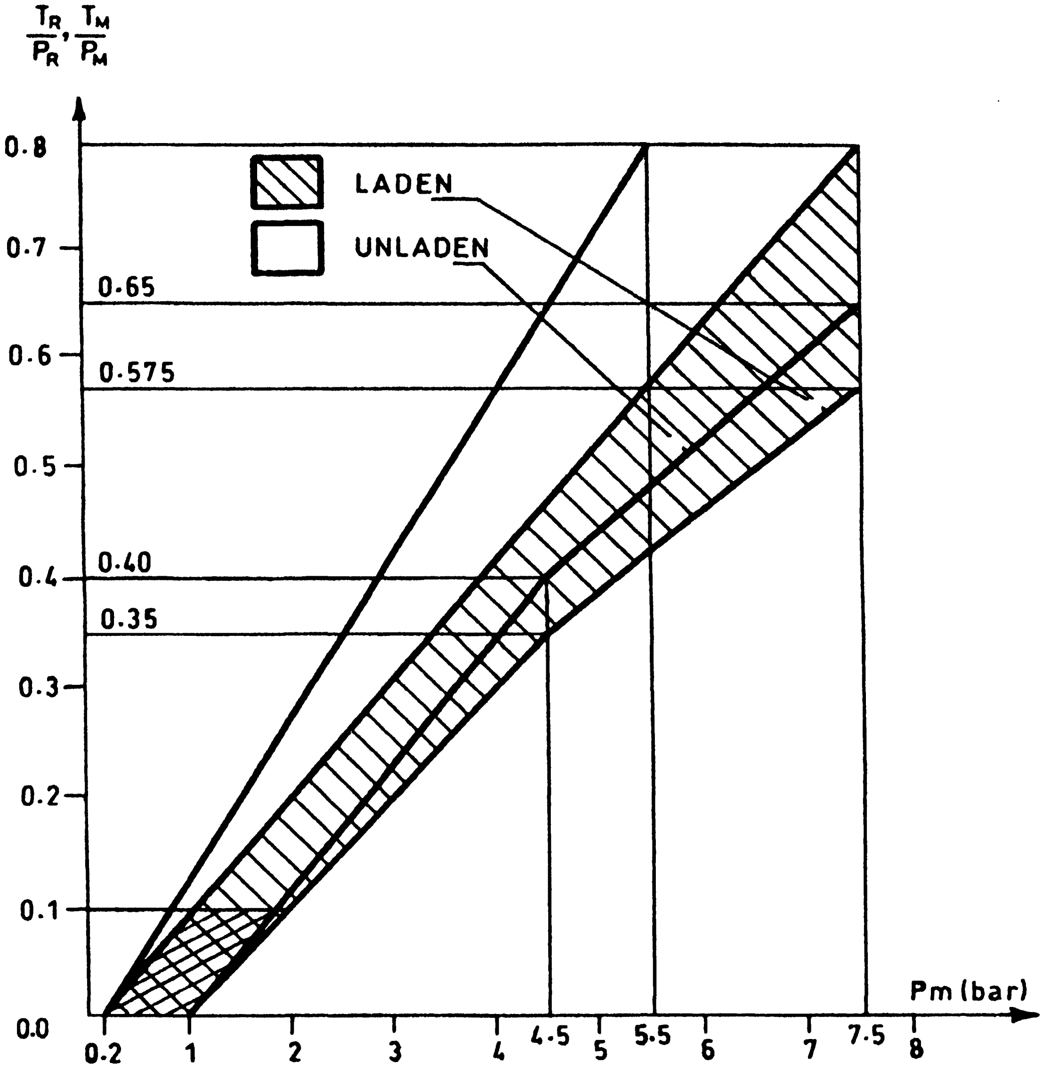
A-7.2.4 The axle load(s) designated by the manufacturer to enable the setting of the device to be checked in service if this is (these are) different from the loads specified in **A-7.2.1** to **A-7.2.3**.

A-7.3 The markings referred to under **A-7.1** and **A-7.2** shall be affixed in a visible position in indelible form. An example of the markings for a mechanically controlled device in a vehicle fitted with compressed air braking is shown in Fig. 6.

A-8 PRESSURE TEST CONNECTIONS

A-8.1 Braking systems incorporating the devices referred to in **A-7.2** shall be fitted with pressure test connections in the pressure line upstream and downstream of the device, at the closest readily accessible positions. The downstream connection shall not be required if the pressure at that point can be checked at the connection required by **6.1** of IS 11852 (Part 4).

A-8.2 The pressure test connections shall comply with **2** of IS 11852 (Part 5).



NOTES

1 It is understood that, between the values

$T_M / P_M = 0$ and $T_M / P_M = 0.1$

or

$T_R / P_R = 0$ and $T_R / P_R = 0.1$

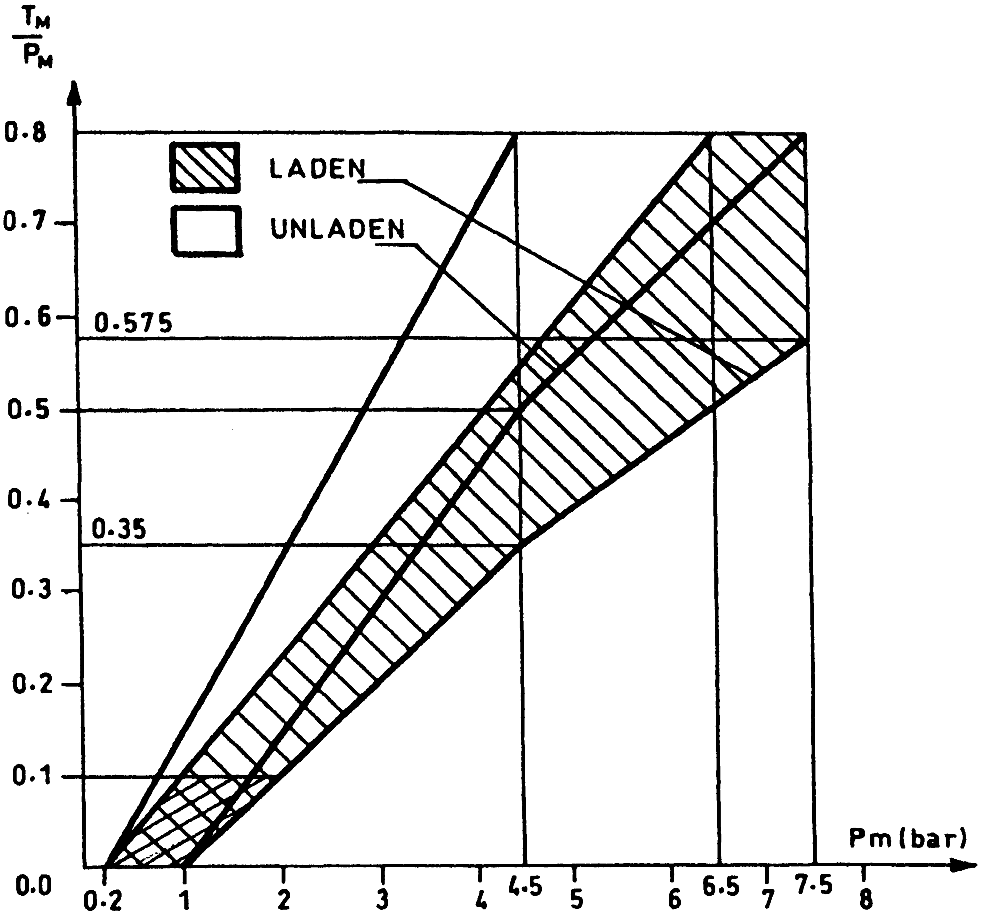
It is not necessary that there should be proportionality between the braking rate

T_M / P_M or T_R / P_R

and the control line pressure as measured at the coupling head.

2 The relationship required by the figure apply progressively for intermediate state of loading/between the laden and the unladen states and shall be achieved by automatic means.

FIG. 2 TOWING VEHICLES AND TRAILERS



NOTES

1 It is understood that, between the values

$T_M / P_M = 0$ and $T_M / P_M = 0.1$

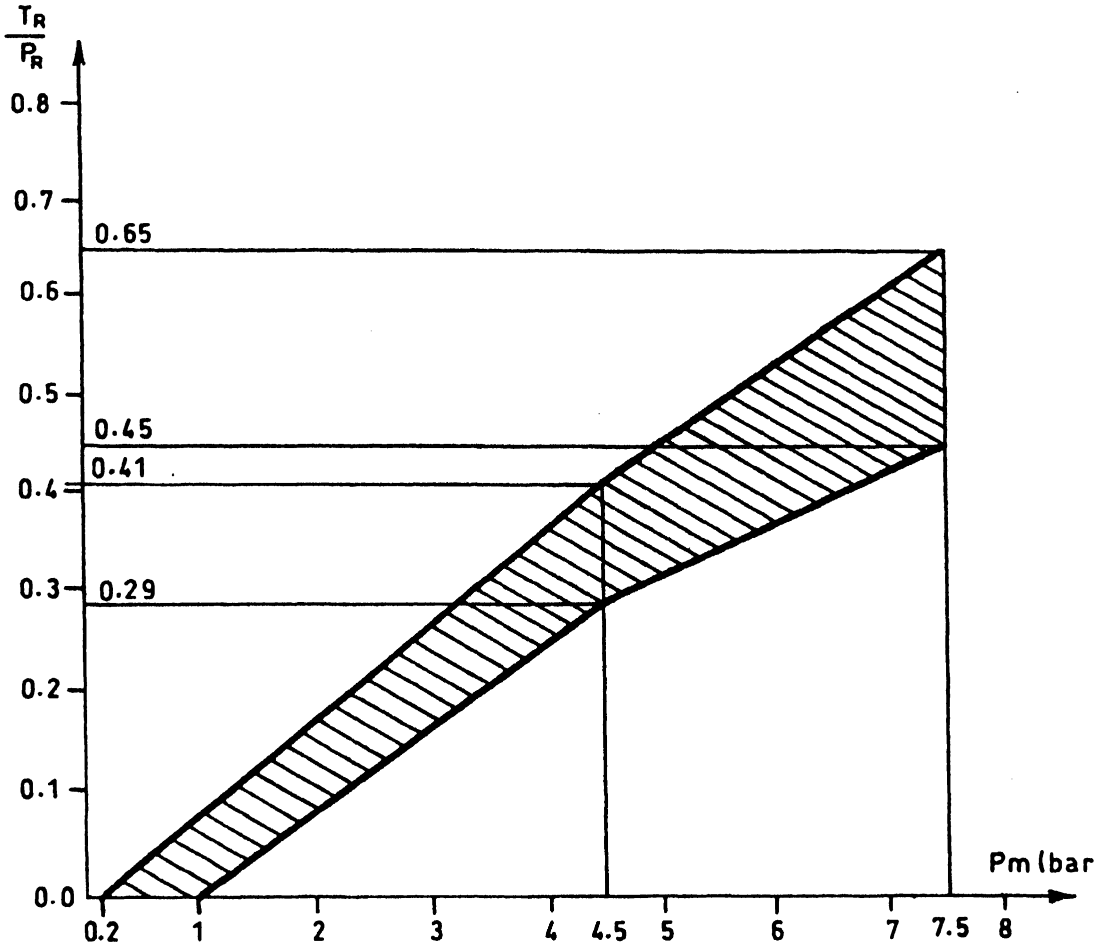
It is not necessary that there should be proportionality between the braking rate

T_M / P_M

and the control line pressure as measured at the coupling head.

2 The relationship required by the figure apply progressively for intermediate state of loading between the laden and the unladen states and shall be achieved by automatic means.

FIG. 3 TRACTIVE UNITS FOR SEMI-TRAILERS



NOTE — It is understood that, between the values

$T_R / P_R = 0$ and $T_R / P_R = 0.1$

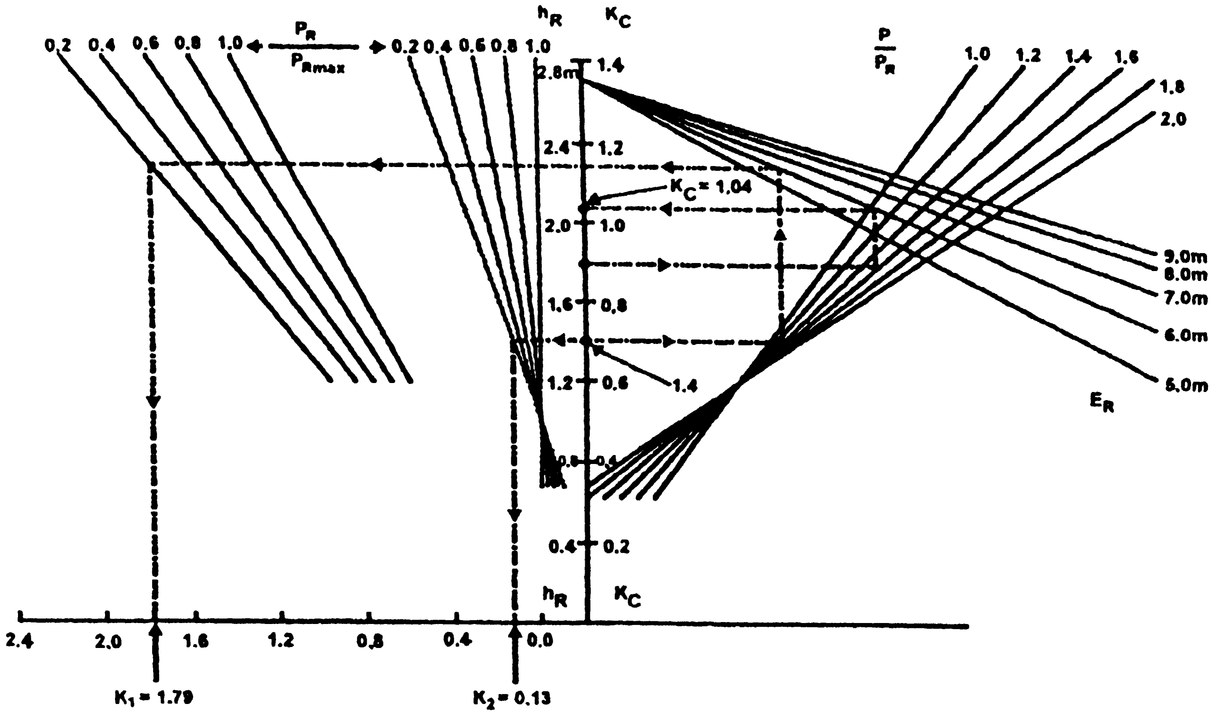
It is not necessary that there should be proportionality between the braking rate

T_R / P_R

And the control line pressure for the laden and unladen conditions is determined as follows:

The factors k_c (laden) and k_v (unladen) are obtained by reference to Fig. 5. Construct the laden and unladen bands by applying the upper and lower boundaries of the band in Fig. 4 by two factors obtained, k_c and k_v respectively.

FIG. 4 SEMI-TRAILERS



NOTES

1 Formula from which Fig. 5 is derived is:

$$k = \left[1.7 - \frac{0.7\,P_R}{P_{R\,max}}\right]\left[1.35 - \frac{0.96}{E_R}\left\{1.0 + (h_R - 1.2)\,\frac{g \times P}{P_R}\right\}\right] - \left[1.0 - \frac{P_R}{P_{R\,max}}\right]\left[\frac{h_R - 1.0}{2.5}\right]$$

2 Description of the method of use by means of a worked example:

a) The dashed lines shown on Fig. 5 refer to the determination of the factors k_c and k_v for the following vehicle where:

	Laden	*Unladen*
P	24 t	4.2 t
P_R	15 t	3 t
$P_{R\,max}$	15 t	15 t
h_R	1.8 m	1.4 m
E_R	6.0 m	6.0 m

In the following items the figures in parenthesis relate only to the vehicle being used for the purpose of illustrating the method of use of Fig. 5.

b) Calculate the ratios:

1) $\left[\frac{P}{P_R}\right]$ laden (= 1.6)

2) $\left[\frac{P}{P_R}\right]$ unladen (= 1.4)

3) $\left[\frac{P}{P_{R\,max}}\right]$ unladen (= 0.2)

FIG. 5 BRAKING RATE FOR SEMI-TRAILOR AXLES – *Contd.*

c) Determination of the laden factor k_c
   1) Start at appropriate h_R (h_R = 1.8 m)
   2) Move horizontally to the appropriate gP/P_R line (gP/P_R = 1.6)
   3) Move vertically to appropriate E_R line (E_R = 6.0 m)
   4) Move horizontally to k_c scale, k_c is the laden factor required (k_c =1.04)

d) Determination of the unladen factor k_v:

   1) Determination of the factor k_2

      i) Start at appropriate h_R (h_R = 1.4 m).

      ii) Move horizontally to appropriate $P_R/P_{R\,max}$ line in group of curves nearest to vertical axis (P_R / $P_{R\,max}$ = 0.2).

      iii) Move vertically to horizontal axis and read off the value of k_2 (k_2 = 0.13 m).

   2) Determination of factor k_1:
      i) Start at appropriate h_R (h_R = 1.4 m).
      ii) Move horizontally to the appropriate gP/P_R line (gP/P_R = 1.4).
      iii) Move vertically to the appropriate E_R line (E_R = 6.0 m).
      iv) Move horizontally to the appropriate $P_R/P_{R\,max}$ line in group of curves furthest from the vertical axis (P_R / $P_{R\,max}$ = 0.2).
      v) Move vertically to horizontal axis and read off the value of k_1 (k_1 = 1.79).

   3) Determination of factor k_v

      i) The unladen factor k_v is obtained from the following expression:

      $k_v = k_1 - k_2$ (k_v = 1.66).

FIG. 5 BRAKING RATE FOR SEMI-TRAILOR AXLES

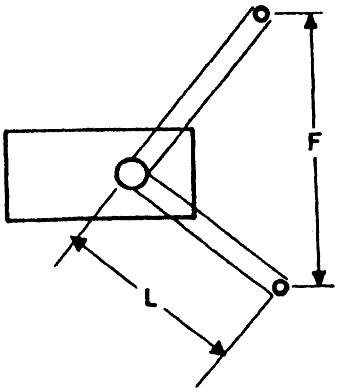
Control Data	*Vehicle Loading*	*Axle No. 2 Load at the Ground* (daN)	*Inlet Pressure* (bar)	*Nominal Outlet Pressure* (bar)
Laden  	Laden	10 000	6	6
F = 100 mm L = 150 mm **Unladen**	Unladen	1 500	6	2.4

FIG. 6 BRAKE LOAD SENSING DEVICE

ANNEX B

(*Clause* 3)

SYMBOLS AND DEFINITIONS

Symbol	*Definitions*
E	Wheelbase
E_R	Distance between king-pin and centre of axle or axles of semi-trailer (or distance between drawbar coupling and centre of axle or axles of centre-axle trailer)
ϵ	Adhesion utilized of the vehicle: quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k)
ϵ_i	ϵ-value measured on axle i (in the case of a power-driven vehicle with a Category 3 anti-lock system)
ϵ_H	ϵ-value on the high-adhesion surface
ϵ_L	ϵ-value on the low-adhesion surface
F	Force (N)
F_{bR}	Braking force of the trailer with the anti-lock system inoperative
$F_{bR\,max}$	Maximum value of F_{bR}
$F_{bR\,max\,i}$	Value of $F_{bR\,max}$ with only axle i of the trailer braked
F_{bRAL}	Braking force of the trailer with the anti-lock system operative
F_{Cnd}	Total normal reaction of road surface on the unbraked and non-driven axles of the vehicle combination under static conditions
F_{Cd}	Total normal reaction of road surface on the unbraked and driven axles of the vehicle combination under static conditions
F_{dyn}	Normal reaction of road surface under dynamic conditions with the anti-lock system operative
F_{idyn}	F_{dyn} on axle i in case of power-driven vehicles or full trailers
F_i	Normal reaction of road surface on axle i under static conditions
F_M	Total normal static reaction of road surface on all wheels of power-driven (drawing) vehicle
F_{Mnd}[1]	Total normal static reaction of road surface on the unbraked and non-driven axles of the power-driven vehicle
F_{Md}[1]	Total normal static reaction of road surface on the unbraked and driven axles of the power-driven vehicle
F_R	Total normal static reaction of road surface on all wheels of trailer
F_{Rdyn}	Total normal dynamic reaction of road surface on the axle(s) of semi-trailer or centre-axle trailer
F_{WM}[1]	$0.01\ F_{Mnd} + 0.015\ F_{Md}$
g	Acceleration due to gravity (9.81 m/s^2)
h	Height of centre of gravity specified by the manufacturer and agreed by the test agency conducting the approval test
h_D	Height of drawbar (hinge point on trailer)
h_K	Height of fifth wheel coupling (king-pin)
h_R	Height of centre of gravity of the trailer
k	Coefficient of adhesion between tyre and road
k_c	Correction factor-semi-trailer laden
k_v	Correction factor-semi-trailer unladen
k_f	k-factor of one front axle
k_H	k-value determined on the high-adhesion surface
k_i	k-value determined on axle i for a vehicle with a Category 3 anti-lock system
k_L	k-value determined on the low-adhesion surface
k_{lock}	value of adhesion for 100 percent slip
k_M	k-factor of the power-driven vehicle
k_{peak}	maximum value of the curve adhesion *versus* slip
k_r	k-factor of one rear axle
k_g	k-factor of the trailer
P	mass of individual vehicle (kg)
P_R	Total normal static reaction of road surface on wheels of trailer or semi-trailer
$P_{R\,max}$	Value of P_R at maximum mass of semi-trailer

---

[1] F_{Mnd} and F_{Md} in case of two-axled power-driven vehicles: these symbols may be simplified to corresponding FI-symbols.

Symbol	*Definitions*
R	ratio of k_{peak} to k_{lock}
t	time interval (s)
t_m	mean value of t
t_{min}	minimum value of t
z	braking rate
z_{AL}	braking rate z of the vehicle with the anti-lock system operative
z_C	braking rate z of the vehicle combination, with the trailer only braked and the anti-lock system inoperative
z_{cal}	braking rate z of the vehicle combination, with the trailer only braked and the anti-lock system operative
$z_{C\,max}$	maximum value of z_C
$z_{C\,max\,i}$	maximum value of z_C with only axle i of the trailer braked
z_m	mean braking rate
z_{max}	maximum value of z
z_{MALS}	Z_{AL} of the power-driven vehicle on a split surface
z_R	braking rate z of the trailer with the anti-lock system inoperative
z_{RAL}	z_{AL} of the trailer obtained by braking all the axles, the drawing vehicle unbraked and its engine disengaged
z_{RALH}	z_{RAL} on the surface with the high coefficient of adhesion
z_{RALL}	z_{RAL} on the surface with the low coefficient of adhesion
z_{RALS}	z_{RAL} on the split-surface
z_{RH}	z_R on the surface with the high coefficient of adhesion
z_{RL}	z_R on the surface with the low coefficient of adhesion
$z_{RH\,max}$	maximum value of z_{RH}
$z_{RL\,max}$	maximum value of z_{RL}
$z_{R\,max}$	maximum value of z_R

ANNEX C

(*Clauses* 6.1.2.1, 6.2.1, 6.2.3 *and* 7.2.1)

UTILIZATION OF ADHESION

C-1 METHOD OF MEASUREMENT FOR POWER-DRIVEN VEHICLES

C-1.1 Determination of the Coefficient of Adhesion (k)

C-1.1.1 The coefficient of adhesion (k) shall be determined as the quotient of the maximum braking forces without locking the wheels and the corresponding dynamic load on the axle being braked.

C-1.1.2 The brakes shall be applied on only one axle of the vehicle under test, at an initial speed of 50 km/h. The braking forces shall be distributed between the wheels of the axle to reach maximum performance. The anti-lock system shall be disconnected, or inoperative, between 40 km/h and 20 km/h.

C-1.1.3 A number of tests at increments of line pressure shall be carried out to determine the maximum braking rate of the vehicle (z_{max}). During each test, a constant input force shall be maintained and the braking rate will be determined by reference to the time taken (t) for the speed to reduce from 40 km/h to 20 km/h using the formula:

z = $0.566 / t$;

z_{max} = maximum value of z;

t = in seconds.

C-1.1.3.1 Wheel lock may occur below 20 km/h.

C-1.1.3.2 Starting from the minimum measured value of t, called t_{min}, then select three values of t comprised within t_{min} and 1.05 t_{min} and calculate their arithmetical mean value t_m, then calculate $z_m = 0.566/t_m$.

If it is demonstrated that for practical reasons the three values defined above cannot be obtained, then the minimum time t_{min} may be utilized. However, the requirements of **C-1.3** shall still apply.

C-1.1.4 The braking forces shall be calculated from the measured braking rate and the rolling resistance of the unbraked axle(s) which is equal to 0.015 and 0.010 of the static axle load for a driven axle and a non-driven axle, respectively.

C-1.1.5 The dynamic load on the axle shall be that given by the formulae in Annex A.

C-1.1.6 The value of k shall be rounded off to three decimal places.

C-1.1.7 Then, the test will be repeated for the other axle(s) as defined in **C-1.1.1.** to **C-1.1.6** (for exemptions *see* **C-1.4** and **C-1.5**).

C-1.1.8 For example, in the case of a two-axle rear-wheel drive vehicle, with the front axle (1) being braked, the coefficient of adhesion (k) is given by:

$$k_f = [\, g\, P\, z_m - 0.015F_2 \,] \,/\, [F_1 + (h.z_m.P.g)/E]$$

C-1.1.9 One coefficient will be determined for the front axle k_f and one for the rear axle k_r.

C-1.2 Determination of the Adhesion Utilized (ϵ)

C-1.2.1 The adhesion utilized (ϵ) is defined as the quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k_M), that is,

$$\epsilon = z_{AL} / k_M$$

C-1.2.2 From an initial vehicle speed of 55 km/h, the maximum braking rate (z_{AL}) shall be measured with full cycling of the anti-lock braking system and based on the average value of three tests, as in **C-1.1.3**, using the time taken for the speed to reduce from 45 km/h to 15 km/h, according to the following formula:

$$z_{AL} = 0.849 / t_m$$

C-1.2.3 The coefficient of adhesion k_M shall be determined by weighing with the dynamic axle loads.

$$k_M = (k_f.F_{fdyn} + k_r.F_{rdyn}) / P.g$$

where

F_{fdyn} = $F_f + (h/E).z_{AL}.P.g$

F_{rdyn} = $F_r - (h/E).z_{AL}.P.g$

C-1.2.4 The value of ϵ shall be rounded off to two decimal places.

C-1.2.5 In the case of a vehicle equipped with an anti-lock system of Categories 1 or 2, the value of z_{AL} will be based on the whole vehicle, with the anti-lock system operative, and the adhesion utilized (ϵ) is given by the same formula quoted in **C-1.2.1**.

C-1.2.6 In the case of a vehicle equipped with an anti-lock system of Category 3, the value of z_{AL} will be measured on each axle which has at least one directly controlled wheel. For example, for a rear wheel drive two-axle vehicle with an anti-lock system acting only on the rear axle, the adhesion utilized (ϵ) is given by:

$$\epsilon_2 = [\, z_{AL}.P.g - 0.010.F_1 \,] \,/\, k_2\, [\, F_2 - (h/E).z_{AL}.P.g \,]$$

This calculation shall be made for each axle having at least one directly controlled wheel.

C-1.3 If $\epsilon > 1.00$ the measurements of coefficients of adhesion shall be repeated. A tolerance of 10 percent is accepted.

C-1.4 For motor vehicles equipped with three axles, only the axle not associated with a close-coupled bogie will be used to establish a k value for the vehicle.

NOTE — Until a uniform test procedure is agreed, vehicles more than three axles and special vehicles will be subjected to consultation with the test agency.

C-1.5 For vehicles of Categories N2 and N3 with a wheelbase less than 3.80 m and with $h/E \geq 0.25$ the determination of the coefficient of adhesion for the rear axle will be omitted.

C-1.5.1 In that case the adhesion utilized (ϵ) is defined as the quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k_{f}), that is

$$\epsilon = z_{\mathrm{AL}} / k_{\mathrm{f}}$$

C-2 METHOD OF MEASUREMENT FOR TRAILERS

C-2.1 General

C-2.1.1 The coefficient of adhesion (k) shall be determined as the quotient of the maximum braking forces without locking the wheels and the corresponding dynamic load on the axle being braked.

C-2.1.2 The brakes shall be applied on only one axle of the trailer under test, at an initial speed of 50 km/h. The braking forces shall be distributed between the wheels of the axle to reach maximum performance. The anti-lock system shall be disconnected or inoperative, between 40 km/h and 20 km/h.

C-2.1.3 A number of tests at increments of line pressure shall be carried out to determine the maximum braking rate of the vehicle combination ($z_{C\,\mathrm{max}}$) with the trailer only braked. During each test, a constant input force shall be maintained and the braking rate will be determined by reference to the time taken (t) for the speed to reduce from 40 km/h to 20 km/h using the formula:

$$z_C = 0.566 / t$$

C-2.1.3.1 Wheel lock may occur below 20 km/h.

C-2.1.3.2 Starting from the minimum measured value of t, called t_{min}, then select three values of comprised within t_{min} and 1.05 t_{min} and calculate their arithmetical mean value t_{m},

then calculate $z_{C\,\mathrm{max}} = 0.566 / t_{\mathrm{m}}$

If it is demonstrated that for practical reasons the three values defined above cannot be obtained, then the minimum time t_{min} may be utilized.

C-2.1.4 The adhesion utilized (ϵ) shall be calculated by means of the formula:

$$\epsilon = z_{\mathrm{RAL}} / k_{\mathrm{g}}$$

The k value has to be determined according to **C-2.2.3** for full trailers or **C-2.3.1** for semi-trailers respectively.

C-2.1.5 If $\epsilon > 1.00$ the measurements of coefficients of adhesion shall be repeated. A tolerance of 10 percent is accepted.

C-2.1.6 The maximum braking rate (z_{RAL}) shall be measured with the anti-lock braking system and the drawing vehicle unbraked, based on the average value of three tests, as in **C-2.1.3**.

C-2.2 Full Trailers

C-2.2.1 The measurement of k (with the anti-lock system being disconnected, or inoperative, between 40 km/h and 20 km/h) will be performed for the front and the rear axles.

For one front axle i:

$$F_{\mathrm{bR\,max\,i}} = z_{C\,\mathrm{max\,i}}\,(F_{\mathrm{M}} + F_{\mathrm{R}}) - 0.01 F_{\mathrm{Cnd}} - 0.015\,F_{\mathrm{Cd}}$$

$$F_{i\mathrm{dyn}} = F_1 + [\,z_{C\,\mathrm{max}}(F_{\mathrm{M}}.h_{\mathrm{D}} + g.\mathrm{P}.h_{\mathrm{R}}) - F_{\mathrm{WM}}.h_{\mathrm{D}}\,] / E$$

$$k_{\mathrm{f}} = F_{\mathrm{bR\,max\,i}} / F_{\mathrm{idyn}}$$

For one rear axle i:

$$F_{\mathrm{bR\,max\,i}} = z_{C\,\mathrm{max\,i}}\,(F_{\mathrm{M}} + F_{\mathrm{R}}) - 0.01 F_{\mathrm{Cnd}} - 0.015\,F_{\mathrm{Cd}}$$

$$F_{\mathrm{idyn}} = F_{\mathrm{i}} - [\,z_{C\,\mathrm{max}}(F_{\mathrm{M}}.h_{\mathrm{D}} + g.P.h_{\mathrm{R}}) - F_{\mathrm{WM}}.h_{\mathrm{D}}\,] / E$$

$$k_{\mathrm{f}} = F_{\mathrm{bR\,max\,i}} / F_{\mathrm{idyn}}$$

C-2.2.2 The values of k_{f} and k_{r} will be rounded to three decimal places.

C-2.2.3 The coefficient of adhesion k_{R} shall be determined proportionally according to the dynamic axle loads.

$$k_{\mathrm{R}} = [\,k_{\mathrm{f}}.F_{\mathrm{fydn}} + k_{\mathrm{r}}\,.\,F_{\mathrm{rdyn}}\,] / P.g$$

C-2.2.4 Measurement of z_{RAL} (with the anti-lock system operative)

$$z_{\mathrm{RAL}} = [\,z_{\mathrm{cal}}.\,(F_{\mathrm{M}} + F_{\mathrm{R}}) - 0.01 F_{\mathrm{Cnd}} - 0.015\,F_{\mathrm{Cd}}\,] / F_{\mathrm{R}}$$

z_{RAL} is to be determined on a surface with a high coefficient of adhesion and, for vehicles with Category A anti-lock system, also on a surface with a low coefficient of adhesion.

C-2.3 Semi-trailers and Centre-Axle Trailers

C-2.3.1 The measurement of k (with the anti-lock system being disconnected or inoperative, between 40 km/h and 20 km/h) shall be carried out with wheels fitted only on one axle, the wheels of the other axle(s) are removed.

$$F_{\mathrm{bR\,max\,i}} = z_{C\,\mathrm{max\,i}}\,(F_{\mathrm{M}} + F_{\mathrm{R}}) - F_{\mathrm{WM}}$$

$$F_{Rdyn} = F_R - [\,F_{bR\,max\,i} \,.\, h_k + z_C \,.\, g.P.(\,h_R - h_k\,)]\,/\,E_R$$

$$k_f = F_{bR\,max\,i}\;/\;F_{Rdyn}$$

C-2.3.2 The measurement of z_{RAL} (with the anti-lock system operative) shall be carried out with all wheels fitted.

$$F_{bRAL} = z_{cal} \,.\, (\,F_M + F_R) - F_{WM}$$

$$F_{Rdyn} = F_R - [\,F_{bRAL} \,.h_k + z_C \,.\, g.P.(\,h_R - h_k\,)]\,/\,E_R$$

$$z_{RAL} = F_{bRAL}\;/\;F_{Rdyn}$$

z_{RAL} is to be determined on a surface with a high coefficient of adhesion and, for vehicles with a Category A anti-lock system, also on a surface with a low coefficient of adhesion.

ANNEX D

(*Clauses* 6.3.5 *and* 7.3.2)

PERFORMANCE ON DIFFERING ADHESION SURFACES

D-1 MOTOR VEHICLES

D-1.1 The prescribed braking rate referred to in **6.3.5** may be calculated by reference to the measured coefficient of adhesion of the two surfaces on which this test is carried out. These two surfaces shall satisfy the conditions prescribed in **6.3.4**.

D-1.2 The coefficient of adhesion (k_H and k_L) of the high- and low-adhesion surfaces, respectively, shall be determined in accordance with the provisions in **C-1.1**.

D-1.3 The braking rate (z_{MALS}) for laden power-driven vehicles shall be:

$$z_{MALS} \geq 0.75.(\,4\,k_L + k_H\,)\,/\,5 \text{ and } z_{MALS} \geq k_L$$

D-2 TRAILERS

D-2.1 The braking rate referred to in **7.3.2** may be calculated by reference to the measured braking rates z_{RALH} and z_{RALL} on the two surfaces on which the tests are carried out with the anti-lock system operative. These two surfaces shall satisfy the conditions prescribed in **7.3.2**.

D-2.2 The braking rate z_{RALS} shall be:

$$z_{RALS} \geq 0.75\,.\,(4.\,z_{RALL} + z_{RALH}\,)\,/\,5\,.\,\epsilon_H$$

$$z_{RALS} > z_{RALL}\,/\,\epsilon_H$$

If $\epsilon_H > 0.95$, use $\epsilon_H = 0.95$

ANNEX E

(*Clause* 6.1.1.2)

METHOD OF SELECTION OF THE LOW-ADHESION SURFACES

E-1 Details of the coefficient of adhesion of the surface selected, as defined in **6.1.1.2**, shall be given to the test agency.

E-1.1 These data shall include a curve of the coefficient of adhesion *versus* slip (from 0 to 100 percent slip) for a speed of approximately 40 km/h.

NOTE — Until a uniform test procedure is established for the determination of adhesion curve for vehicles with a minimum mass exceeding 3.5 t, the curve established for passenger cars may be used. In this case for such vehicles, the ratio k_{peak} and k_{lock} shall be established using a value of k_{lock} as defined in Annex C.

With the consent of the test agency, the coefficient of adhesion described in this para may be determined by another method provided that the equivalence of the values of k_{peak} and k_{lock} are demonstrated.

E-1.1.1 The maximum value of the curve will represent k_{peak} and the value at 100 percent slip will represent k_{lock}.

E-1.1.2 The ratio R shall be determined as the quotient of the k_{peak} and k_{lock}

$$R = k_{peak} / k_{lock}$$

E-1.1.3 The value of R shall be rounded off to one decimal place.

E-1.1.4 The surface to be used shall have a ratio R between 1.0 and 2.0.

NOTE — Until such test surfaces become generally available, a ratio R up to 2.5 is acceptable, subject to discussion with the test agency.

E-2 Prior to the tests, the test agency shall ensure that the selected surface meets the specified requirements and shall be informed of the following:

a) Test method to determine R,

b) Type of vehicle (motor vehicle, trailer, . . .), and

c) Axle load and tyres (different loads and different tyres have to be tested and the results shown to the test agency which will decide if they are representative for the vehicle to be approved).

E-2.1 The value of R shall be mentioned in the test report.

E-2.2 The calibration of the surface has to be carried out at least once a year with a representative vehicle to verify the stability of R.

ANNEX F

(Foreword)

COMMITTEE COMPOSITION

Automotive Braking Systems, Vehicle Testing and Performance Evaluation Sectional Committee, TED 4

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This Indian Standard has been developed from Doc: No. TED 4 (237).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402

Telegrams: Manaksanstha
(Common to all offices)

Regional Offices:

		Telephone
Central	: Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	2323 7617 2323 3841
Eastern	: 1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi KOLKATA 700054	2337 8499, 2337 8561 2337 8626, 2337 9120
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Printed at Simco Printing Press, Delhi